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DATA REPORT OF 0.055-SCALE APOLLO DYNAMIC
STABILITY MODEL (FD-2) TESTS TO DETERMINE
FLOW SEPARATOR EFFECTS — HIGH MACH LEG
OF THE Langley UNITARY PLAN
WIND TUNNEL (PROJECT 411)

NAS9-150

(U)

April 1963



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FOREWORD

The investigation to determine flow separator effects was conducted under NASA Apollo contract NAS9-150 on 16 November 1962 in the high Mach leg Langley Unitary Plan Wind Tunnel.

This report was prepared by C. E. Mitchell and C. L. Berthold of the Wind Tunnel Projects Group, Los Angeles Division of North American Aviation, Inc.

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I. INTRODUCTION

Dynamic stability tests were conducted on the 0.055-scale Apollo model (FD-2) in the Langley Unitary Plan Wind Tunnel (high Mach leg) on 16 November 1962 to determine the dynamic stability derivatives for the current launch escape configuration (116-inch tower and 280-inch rocket) in the supersonic speed range. Data were obtained at Mach numbers 3.00, 3.50, 3.96, and 4.65 for flow separator disc on and off with the oscillation center on the design center of gravity of the full-scale vehicle.

Reynolds numbers, based on maximum model diameter, were in the order of $1/91 \times 10^6$ to 2.63×10^6 . All dynamic stability derivatives were measured during forced oscillation of the model in pitch only with an amplitude of approximately ± 2 degrees about the oscillation center at angles of attack from -18 to +4 degrees.

This report presents only basic wind tunnel data so that the test results can be made available at the earliest possible date. Analysis of results will be reported in a separate publication.

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II. DISCUSSION

In previous tests at supersonic speeds, physical limitations imposed by the size of the model and the dynamic balance made it impossible to locate the oscillation center ideally on the design center of gravity of the full-scale vehicle. On the current model, the command module apex was modified within the confines of the tower legs to allow positioning of the balance oscillation center on the design center of gravity. Investigations were made with flow separator disc on and off (configurations E₅₂T₂₁C₁₉ and E₅₁T₂₁C₁₉).

Reynolds numbers of 3.0×10^6 to 4.0×10^6 were requested for this test, but because of a limitation of available power (40 megawatts maximum), Reynolds numbers in the order of 1.91×10^6 to 2.63×10^6 were obtained.

Several techniques are available for measuring dynamic stability derivatives of models in wind tunnels. This test was performed using the "inexorable" method in which the model is mechanically forced to oscillate in a single degree of freedom at a known angular frequency and amplitude (± 2 degrees) while measurements are made of the moment required to sustain the motion. -A more complete description of the apparatus and methods used can be found in References 2 and 6.

Plotted and tabular data are presented in the appendixes and in NASA standard coefficient form referred to the body system of axes originating at the oscillation center. Dynamic stability parameters are employed to indicate the aerodynamic damping in pitch ($C_{m\dot{\alpha}} + C_{m\ddot{\alpha}}$) and oscillatory longitudinal stability ($C_{m\dot{\alpha}} - k^2 C_{m\ddot{\alpha}}$) for tests with oscillations in pitch. The plotted data present these parameters as a function of angle of attack.

Because of a malfunction in the Schlieren system, photographs were obtained at only Mach number 4.65 for the disc-on configuration ($\alpha = -2$, -4 , and -8 degrees). This problem was later corrected, and photographs were obtained at Mach numbers 3.00, 3.50, 3.96, and 4.65 with the disc off ($\alpha = 0$, -4 , and -8 degrees). These Schlieren photographs were taken at set angles of attack (nonoscillating model) and are presented in Figures 8 through 12.

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III. MODEL DESCRIPTION

The 0.055-scale Apollo FD-2 model tested was of the current launch escape configuration (116-inch tower and 280-inch rocket). To reduce moment-of-inertia effects, the model was constructed from lightweight materials whenever consistent with the structural integrity as established in Reference 7. The command module was constructed of aluminum alloy (7075-T6); the escape tower was constructed of Armco steel (17-4PH SST); and escape rocket was constructed of magnesium (QQ-M-31). All parts were aerodynamically smooth.

The apex of the command module was modified within the confines of the tower legs to allow the oscillation center of the balance to be positioned on the design center of gravity of the full scale vehicle. This altered command module is shown in Figure 5.

To allow pitching through angles of attack near proposed flight attitudes, the launch escape system was constructed so that its axis of symmetry and balance centerline formed an angle of 8 degrees.

MODEL NOMENCLATURE

Symbol	Description	Drawing No.	Sketch
E ₅₁	Escape motor. Length = 279.65 in.; 36° 55' flared skirt.	7121-01072-4 -11	Figure 3
E ₅₂	Escape motor. Length = 279.65 in.; 36° 55' flared skirt with 65 in. diameter flow separator disc and fairing from disc to skirt.	7121-01072-4 -6-11	Figure 3
T ₂₁	Tower structure. Length = 116.1 in.	7121-01072-9	Figure 4
C ₁₉	Command module. Maximum diameter = 154.0 in. Apex altered to correctly position balance.	7121-01072-3 -5-7	Figure 5

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FULL-SCALE DIMENSIONS

Escape Rocket, E₅₁

Total length	279.65 in.
Diameter	26.00 in.
Nose radius	2.00 in.
Nose included angle	30.00 deg
Skirt base diameter	54.60 in.
Skirt flare angle	36.92 deg
Diameter of ring forward of skirt	28.87 in.

Escape Rocket, E₅₂

Same as E₅₁ with flow separator disc located 19.16 in. from base of rocket motor and a fairing extending from aft end of disc to flared skirt.

Flow separator disc diameter	65.00 in.
Flow separator disc thickness	2.00 in.
Fairing diameter	51.08 in.

Tower, T₂₁

Total length	116.10 in.
Diameter of longitudinal members (4 members)	3.40 in.
Diameter of cross braces	2.49 in.
Diameter of diagonal braces	2.49 in.
Distance between attachment points	50.18 in.

Command Module, C₁₉

Max. diameter	154.00 in.
Radius of spherical blunt end	184.80 in.
Corner radius	7.58 in.
Nose cone semiangle	33.00 deg
Nose cone vertex radius	15.40 in.
Frontal area	129.35 ft ²

Apex was modified within the confines of the tower legs to allow the oscillation center of the balance to be positioned on the design center of gravity of the full-scale vehicle.

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IV. TEST PROCEDURE

TEST NOMENCLATURE

The following nomenclature was used during this investigation.

- A Maximum cross-sectional area, ft^2 , $\frac{\pi \ell^2}{4}$
- ℓ Maximum body diameter, ft
- P Free-stream static pressure, lb/ft^2
- q_∞ Free-stream dynamic pressure, lb/ft^2
- α Angle of attack of model centerline, deg or radians
- $\dot{\alpha}$ Rate of change of angle of attack, radians/sec
- V Free-stream velocity, ft/sec
- M Mach number
- ω Angular frequency of oscillation, radians/sec
- k Reduced frequency parameter, $\frac{\omega \ell}{V}$
- R Reynolds number based on ℓ
- q Angular velocity in pitch, radians/sec
- \dot{q} Rate of change of pitching angular velocity, radians/sec²
- I Moment of inertia, slug-ft²
- C_m Pitching moment coefficient, $\frac{\text{pitching moment}}{q_\infty A \ell}$
- $C_{m_q} + C_{m_{\dot{\alpha}}}$ Damping-in-pitch parameter per radian
- $C_{m_a} - k^2 C_{m_q}$ Oscillatory longitudinal stability parameter per radian

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MODEL INSTALLATION

The FD-2 model was installed on the NASA 1600 inch-pound dynamic balance (Drawing 401896) that was mounted on a straight sting containing the oscillating mechanism. The drive motor, clutch resolvers, and frequency generator were all contained in the downstream end of the sting, which was stiffened to provide a resonant frequency above the maximum oscillating frequency of the model. The oscillating mechanism was designed to provide maximum stiffness of all drive linkages so that the model responded only to the essentially sinusoidal forcing input of the crank and Scotch yoke.

The model was mounted so that the sting centerline and command module axis of symmetry formed an angle of 8 degrees to allow testing through angles of attack of -20 to +8 degrees. The tunnel basic sting-type support system, which is mounted on a horizontal strut extending from wall to wall, was fitted with a special knuckle to allow pitching of the model in the vertical plane.

INSTRUMENTATION

The NASA 1600 inch-pound dynamic pitch balance was used to measure the moment and displacement functions as the model was mechanically forced to oscillate in a single degree of freedom.

In operation of the system, calibrated outputs of the moment and displacement strain gages are passed through coupled electrical sine-cosine resolvers that rotate at the frequency of oscillation. The resolvers transform the outputs into orthogonal components from which the resultant applied moment and displacement and the phase angle between them were found. With the known oscillation frequency, the aerodynamic damping and oscillatory stability moments are computed.

All data were computed on a remotely located IBM 7090 computer.

DATA REDUCTION AND CONSTANTS

All data were reduced and presented in standard NASA coefficient form referred to the body system of axes originating at the oscillation center. The equations used in reducing the data are as follows:

C - System damping moment in.-lb/rad/sec
K - System spring constant, in.-lb/rad

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$$C_{aero} = C_{run} - C_{tare}, \text{ where } C_{tare} = \text{constant}$$

$$(K - I\omega^2)_{aero} = (K - I\omega^2)_{run} - (K - I\omega^2)_{tare}$$

$$C_{m_q} + C_m \dot{\alpha} = - \frac{V C_{aero}}{12 q_\infty A l^2}$$

$$C_m \dot{\alpha} - k^2 C_{m_q} = - \frac{(K - I\omega^2)_{aero}}{12 q_\infty A l^2}$$

where

$$k = \frac{\omega l}{V}$$

$$q_\infty = 0.7 p M^2$$

$$p = \frac{\text{stagnation pressure}}{(1 + 0.2M)^{3.5}}$$

$$V = \frac{(49.0236) \sqrt{T_t M}}{(1 + 0.2M)^{3.5}} ; T_t = \text{tunnel total temperature, } {}^\circ\text{R}$$

$$\text{Reynolds number} = \frac{2l q_\infty}{\mu V}; \mu = \text{viscosity, } \frac{\text{lb-sec}}{\text{ft}^2}$$

The following were constants for the test:

$$l = 0.7058 \text{ ft}$$

$$A = 0.3912 \text{ ft}^2$$

DATA ACCURACY

The estimated probable errors of the aerodynamic test conditions for this test are as follows:

k , radians ± 0.0001

M ± 0.005

R $\pm 0.005 \times 10^6$

α , degrees ± 0.2

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The ability of the forced oscillation equipment and instrumentation used to measure accurately the system damping and stability moments in these tests is discussed in Reference 6. These accuracies in measuring applied moments, based on repeatability in measuring the wind-off or tare moments of the model and mechanical system when translated to coefficient form using the dimensions of the 0.055-scale Apollo models, give these probable coefficient accuracies:

$$C_{m_q} + C_{m_a} \pm 0.06$$

$$C_{m_a} - k^2 C_{m_q} \pm 0.03$$

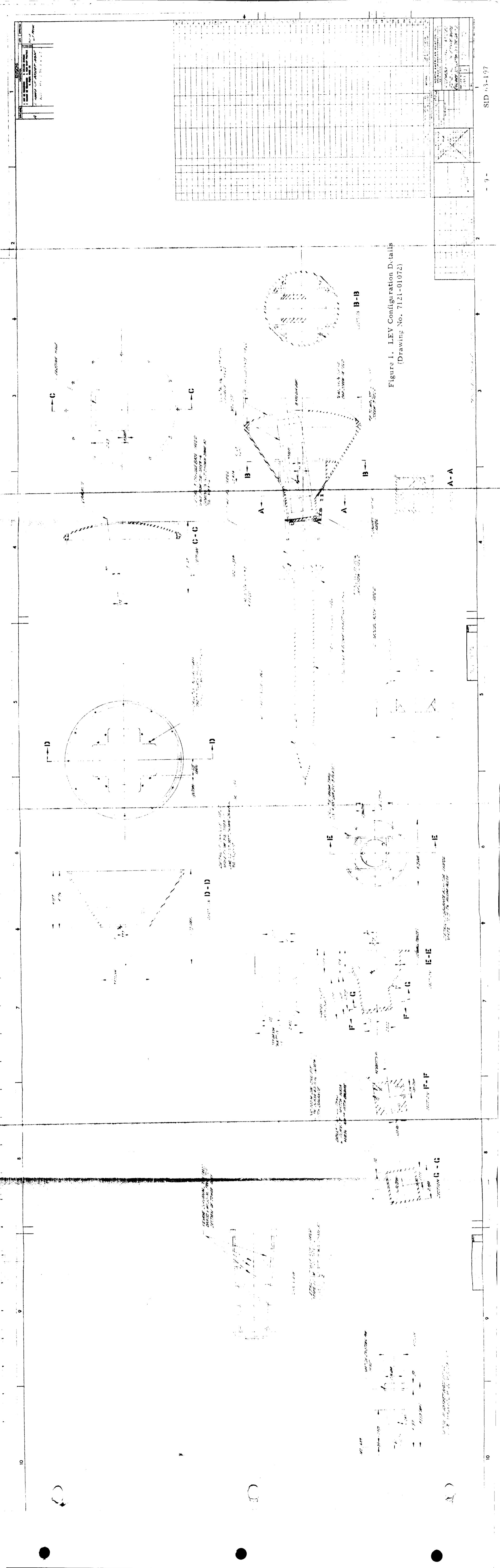


Figure 1. LEV Configuration Details
(Drawing No. 7121-01072)



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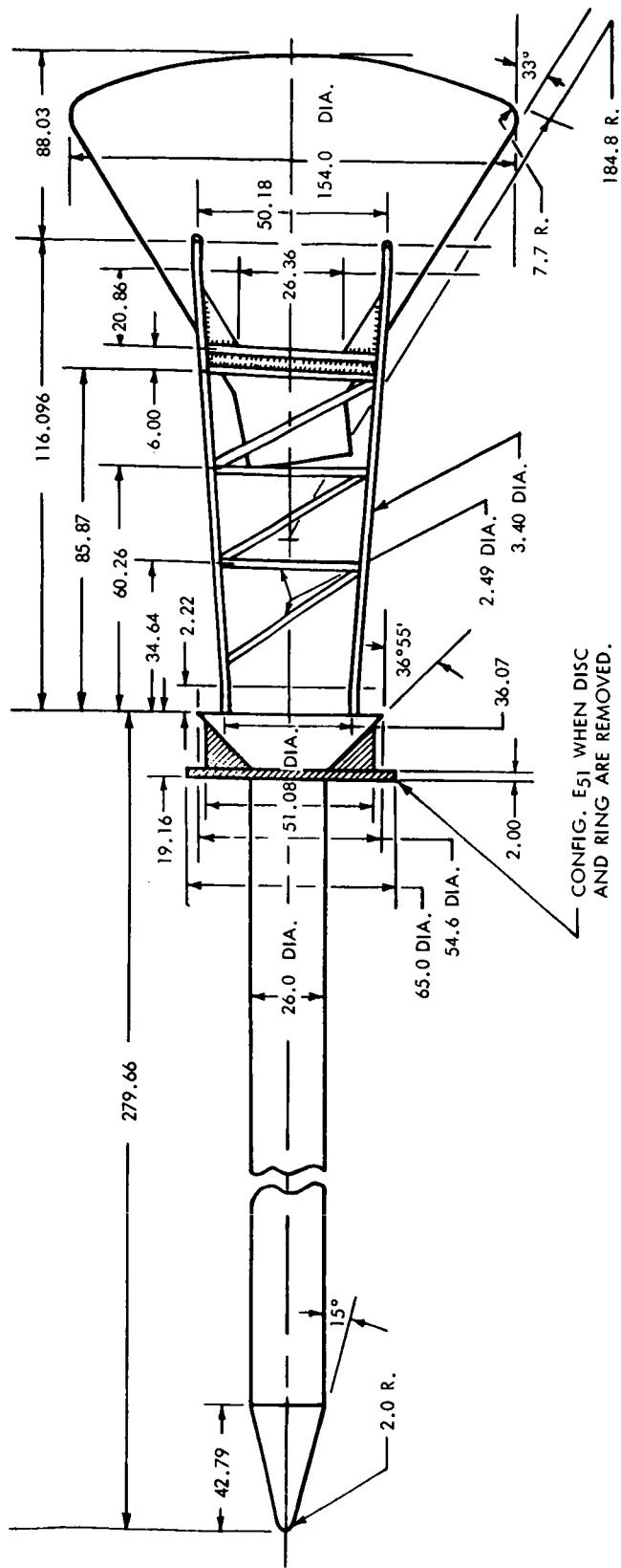


Figure 2. LEV Configuration E52 T21C19

FULL-SCALE DIMENSIONS IN INCHES
DRAWING NOT TO SCALE



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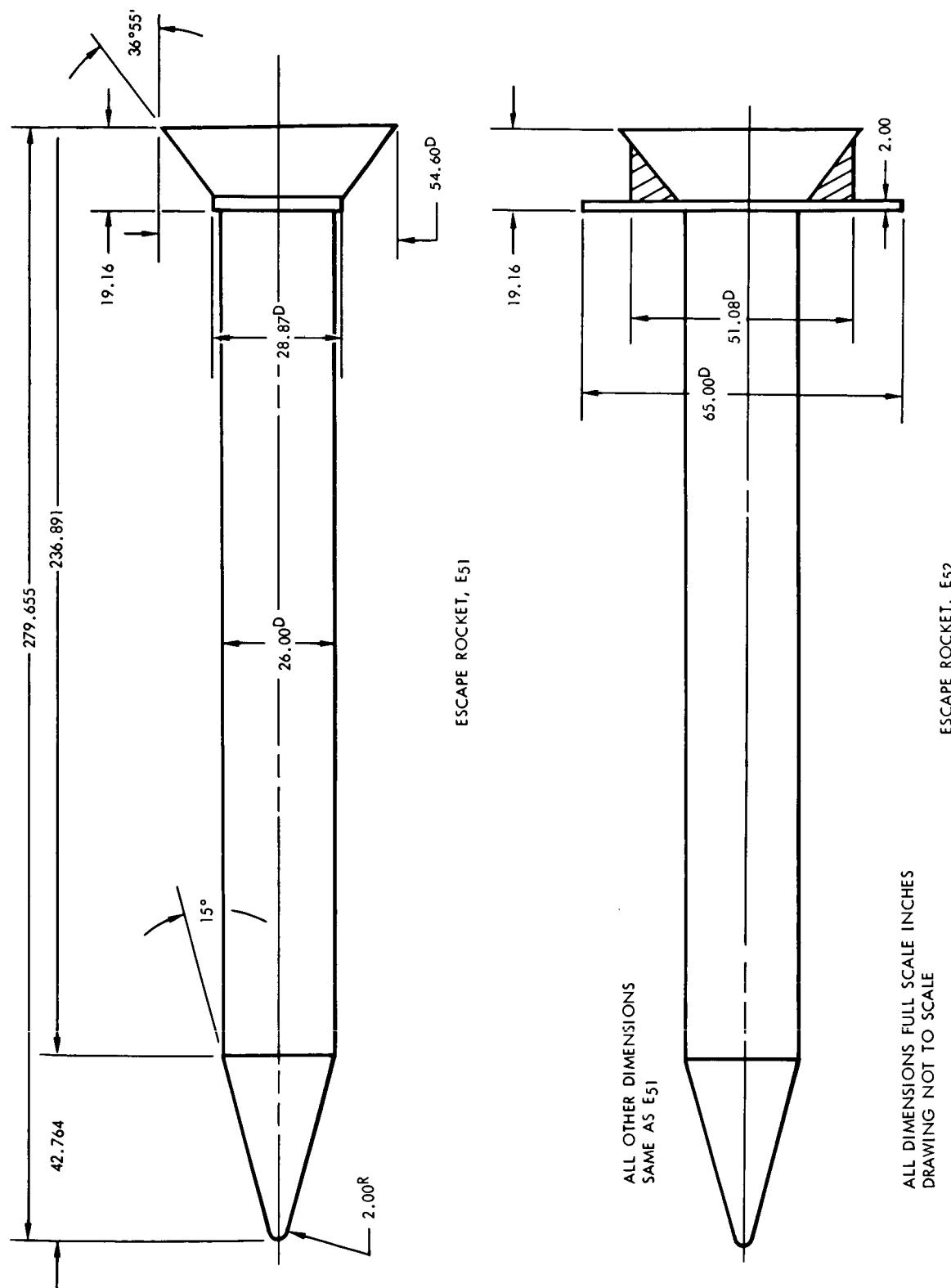


Figure 3. Escape Rocket Configurations

ESCAPE ROCKET, E52

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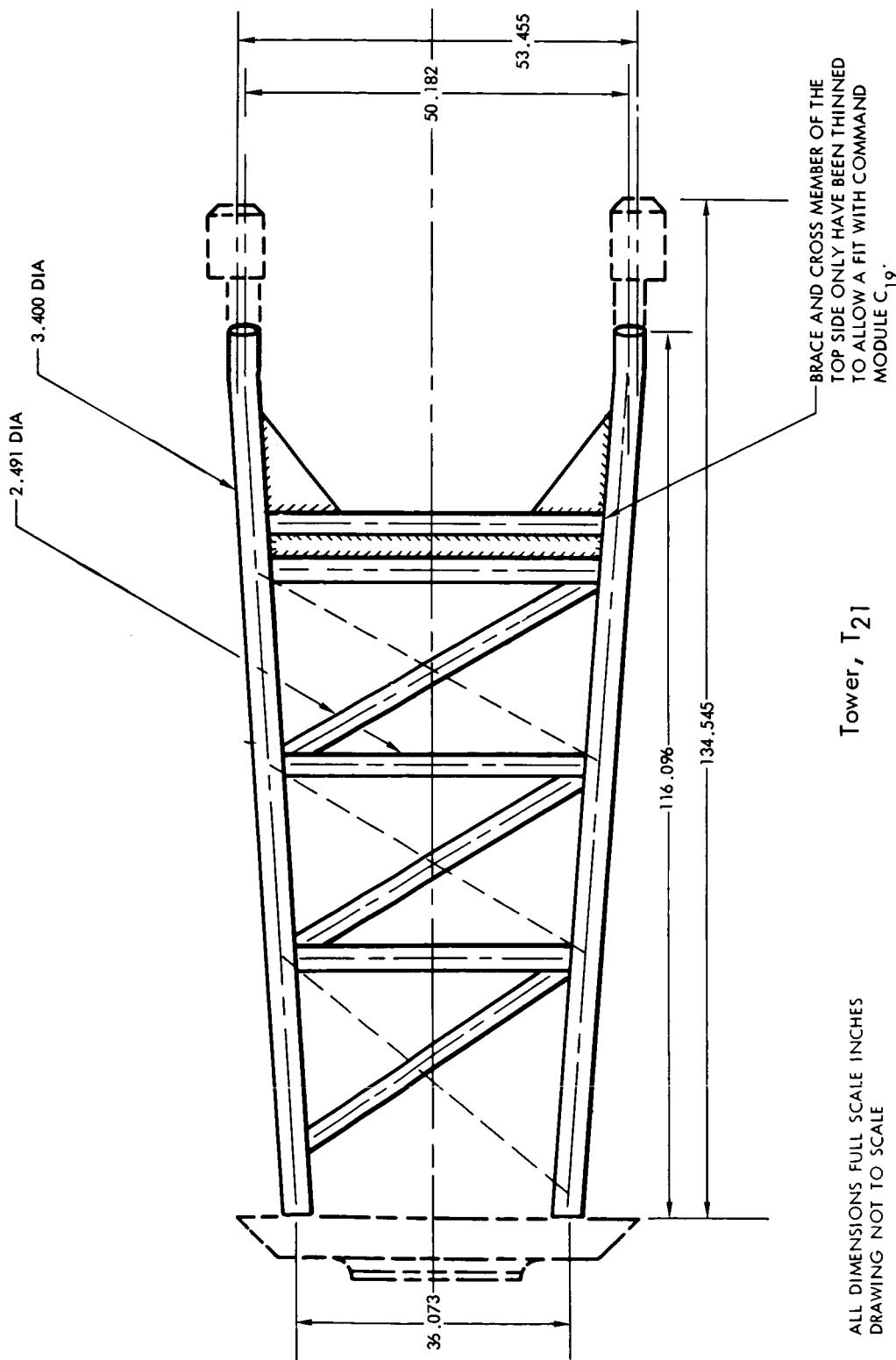
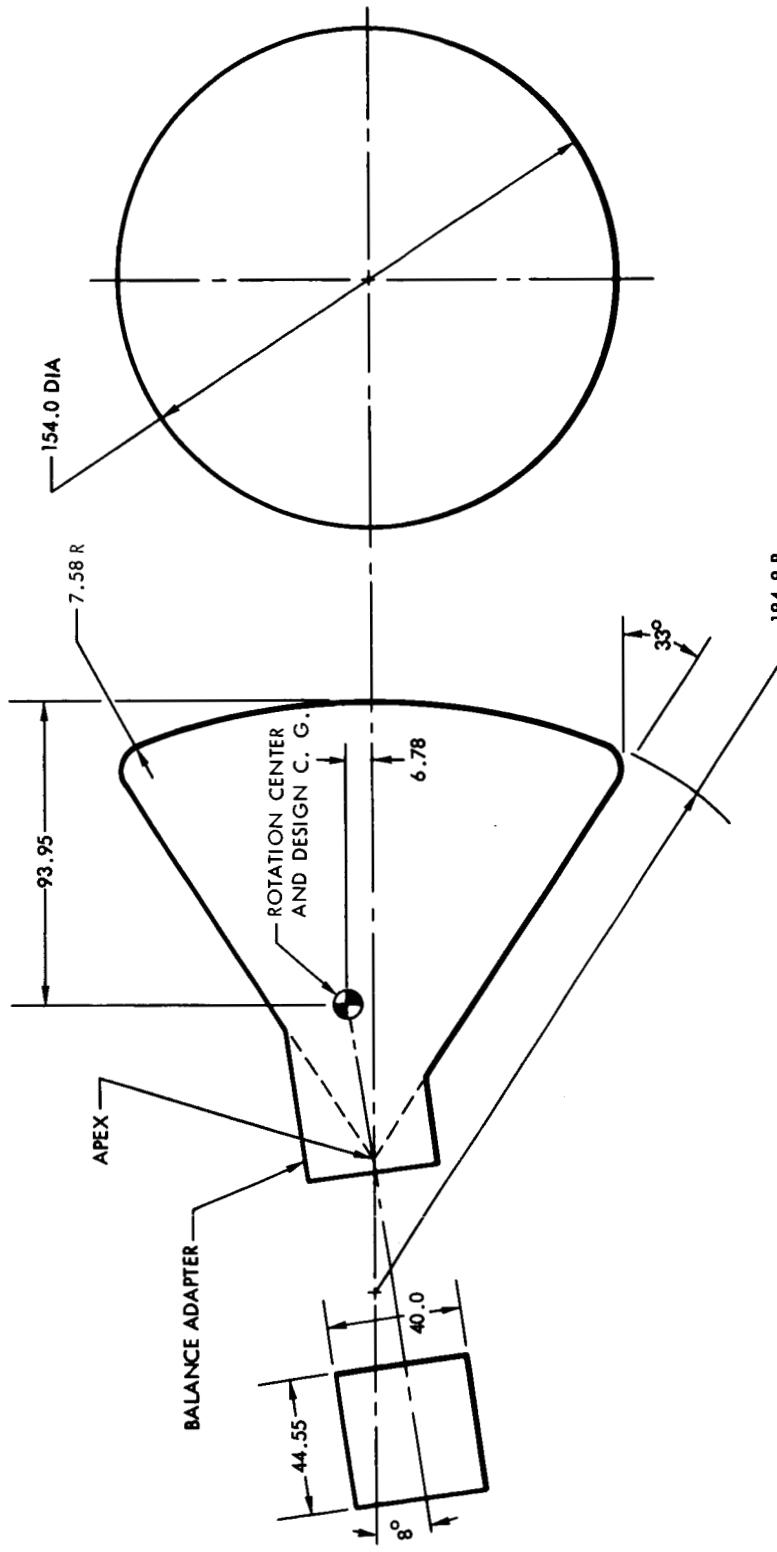
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Figure 4. Tower Structure

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ALL DIMENSIONS FULL SCALE INCHES
DRAWING NOT TO SCALE

Command Module, C19

Figure 5. Command Module for LEV Configuration

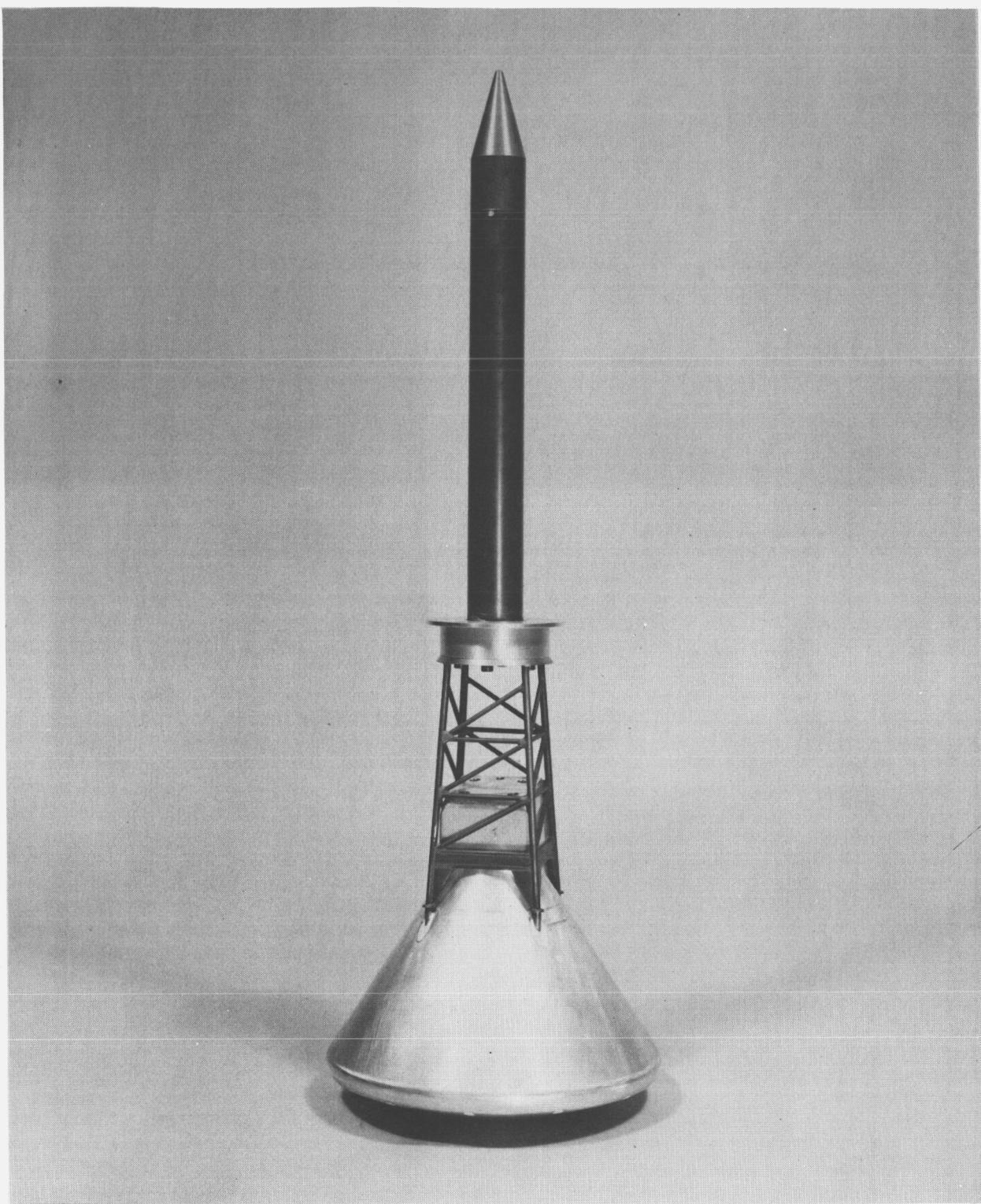
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Figure 6. LEV With Flow Separator Disc

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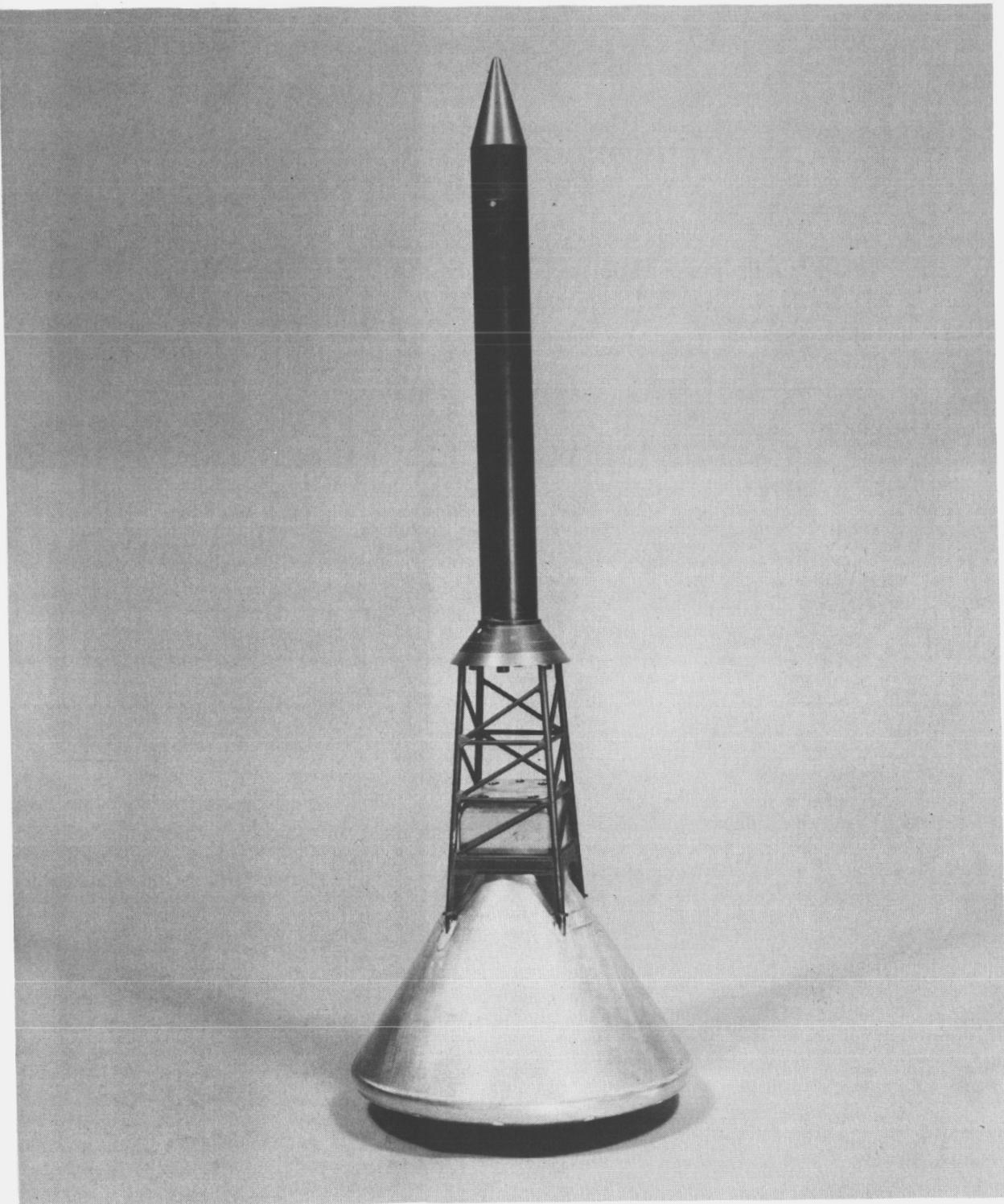
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Figure 7. LEV Without Flow Separator Disc

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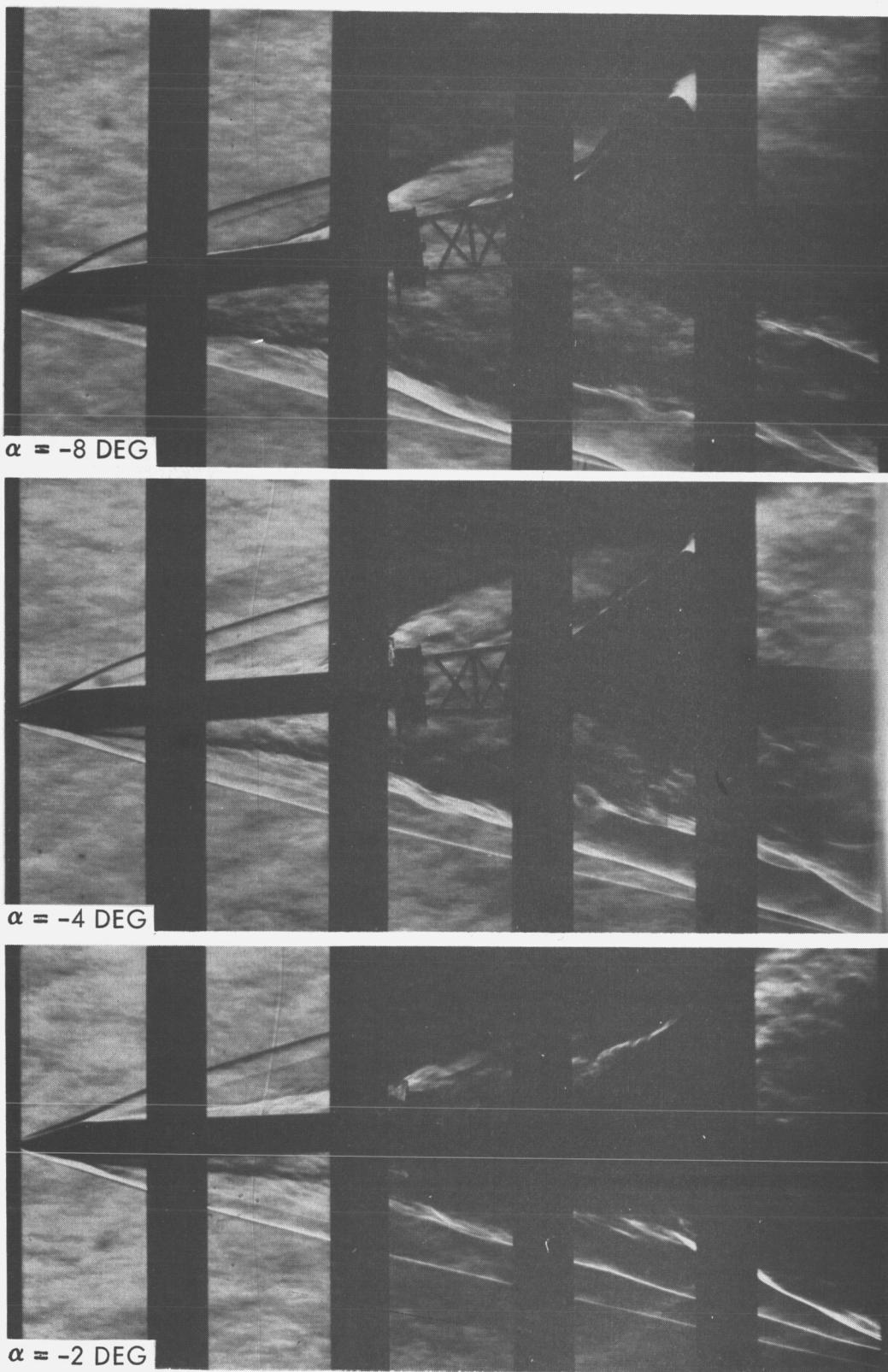
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Figure 8. Typical Schlierens of E₅₂T₂₁C₁₉ Configuration
at M = 4.65 and R = 2.63 × 10⁶

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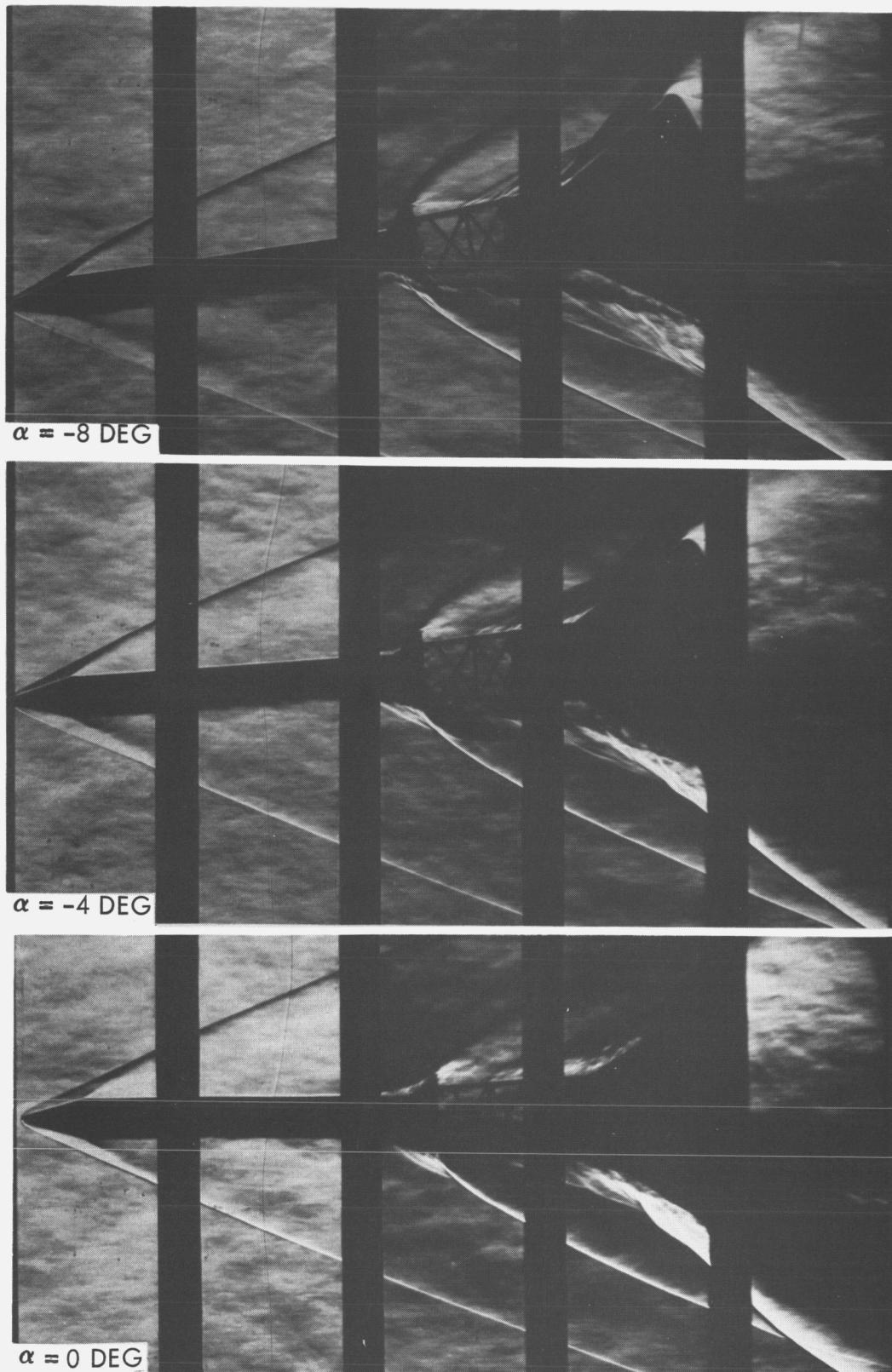
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Figure 9. Typical Schlierens of E₅₁T₂₁C₁₉ Configuration
at M = 3.00 and R = 1.97 × 10⁶

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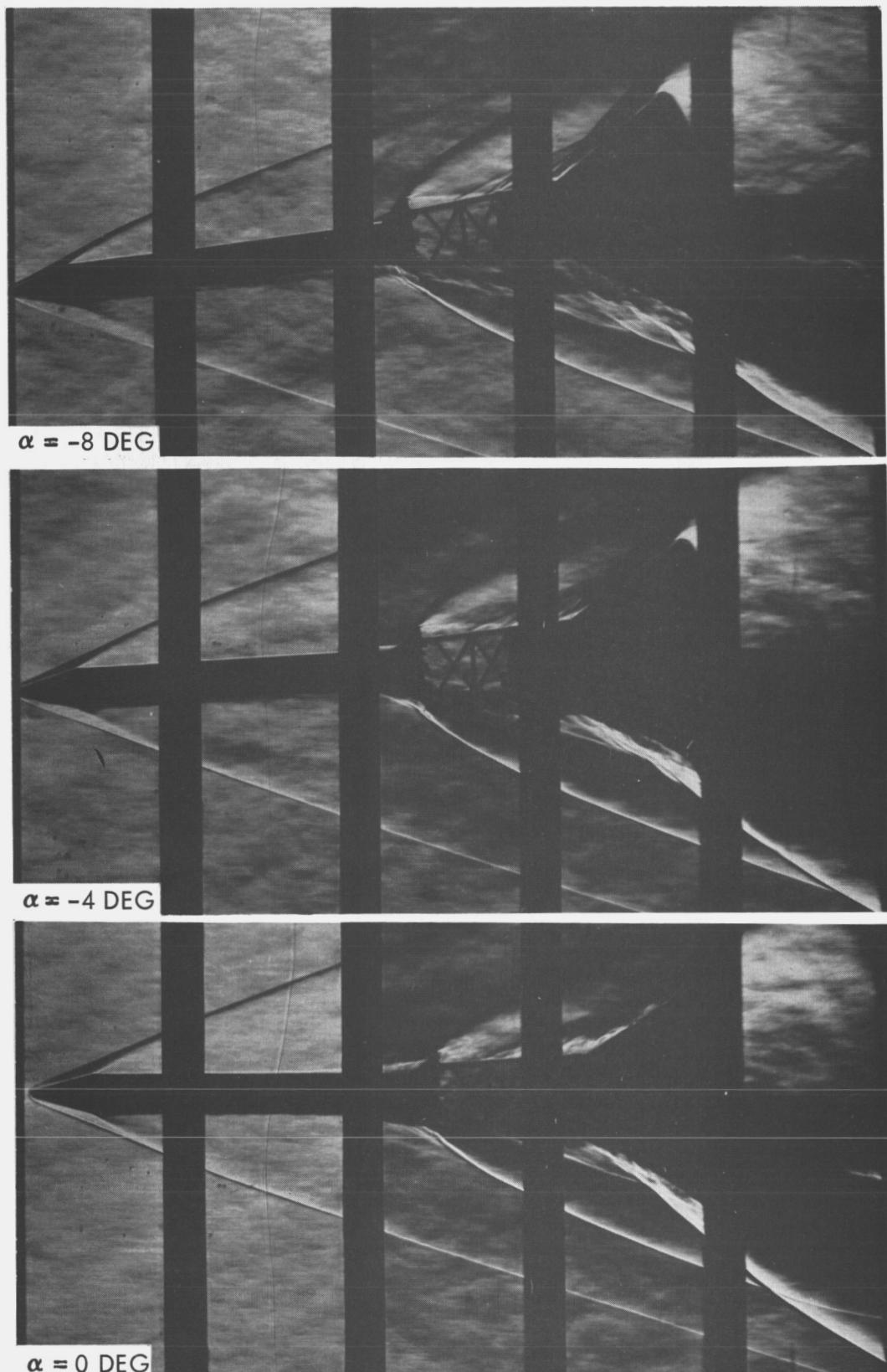
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Figure 10. Typical Schlierens of E51T21C19 Configuration
at $M = 3.50$ and $R = 2.36 \times 10^6$

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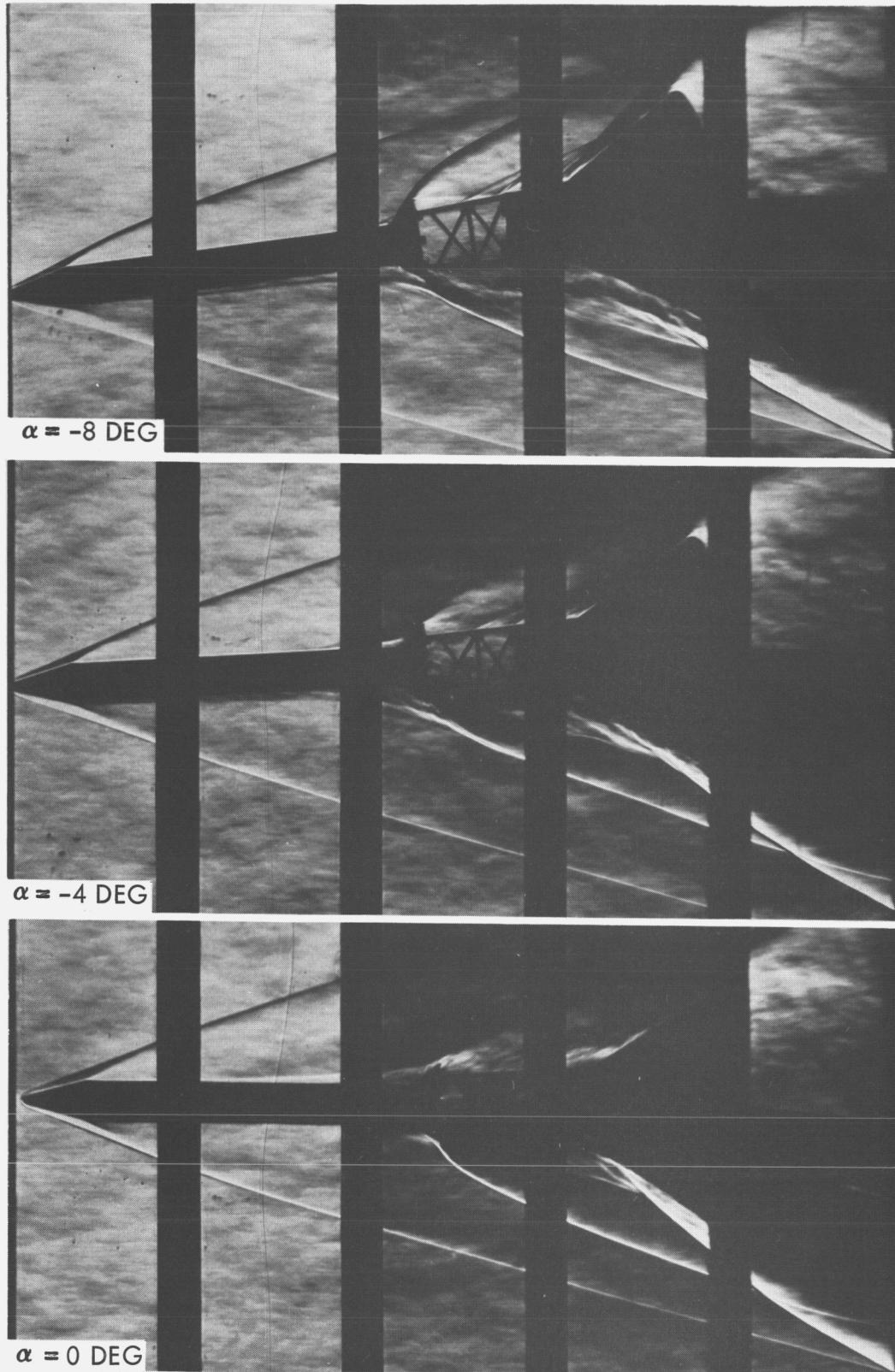
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Figure 11. Typical Schlierens of E₅₁T₂₁C₁₉ Configuration
at $M = 3.96$ and $R = 2.05 \times 10^6$

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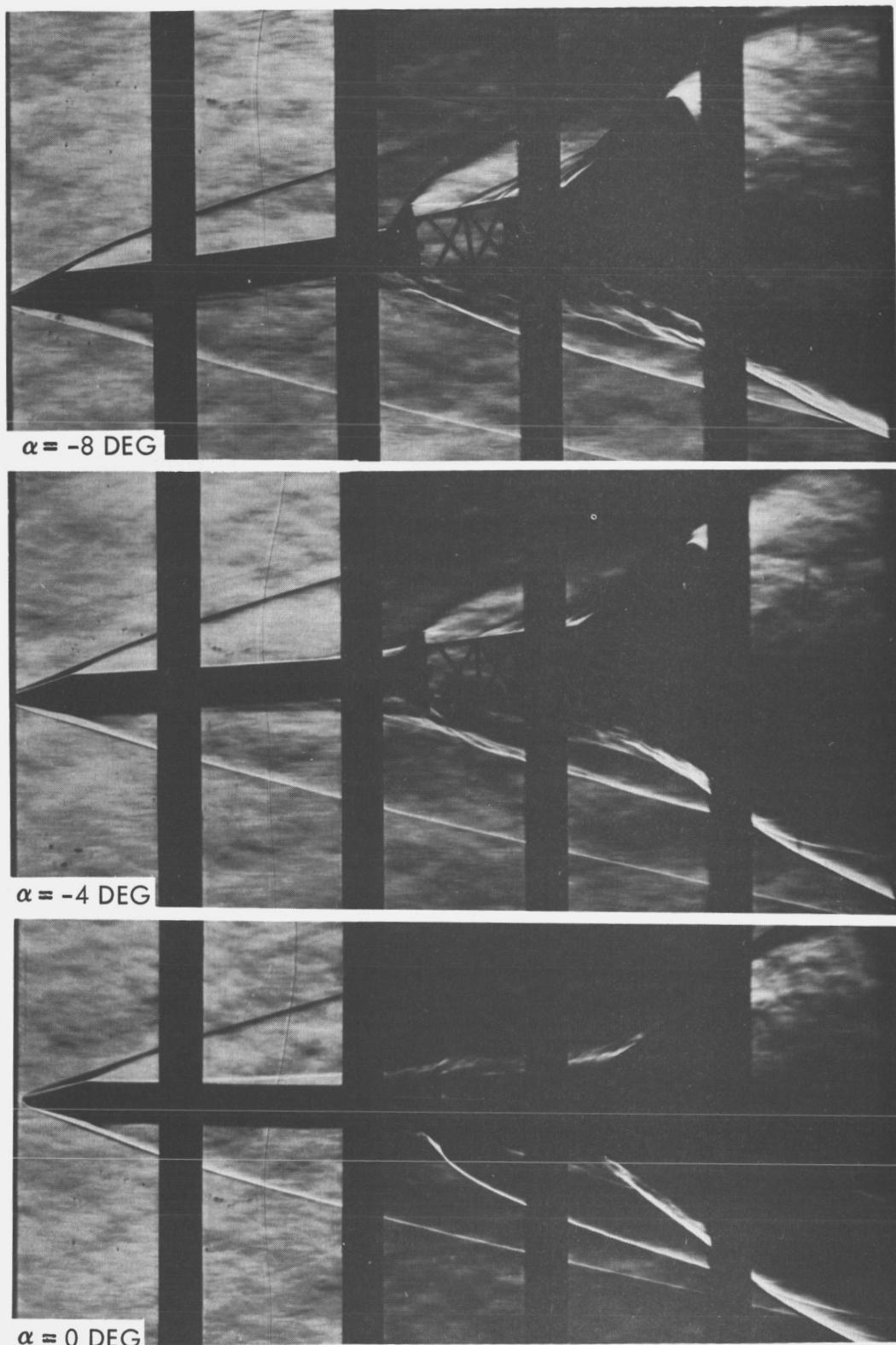
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Figure 12. Typical Schlierens of E51T21C19 Configuration
at $M = 4.65$ and $R = 2.63 \times 10^6$

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V. REFERENCES

1. Data Report for Langley 8-Foot TPT Wind Tunnel Tests (Project 233) of Apollo Model (FD-2). NAA S&ID SID 62-1065 (24 August 1962).
2. Data Report for Langley Unitary Plan Wind Tunnel Tests (Project 349) of Apollo Model (FD-2). NAA S&ID SID 62-536 (28 May 1962).
3. Data Report for Langley Unitary Plan Wind Tunnel Tests (Project 374) of Apollo Model (FD-2). NAA S&ID SID 62-1074 (24 August 1962).
4. Data Report for Tests of a 0.055-Scale Apollo Dynamic Stability Model (FD-2) in the Low Mach Leg of the Langley Unitary Plan Wind Tunnel (Project 398). NAA S&ID SID 63-96 (April 1963).
5. Data Report for Tests of a 0.055-Scale Apollo Dynamic Stability Model (FD-2) to Determine Flow Separator Effects - Langley 8-Foot Transonic Pressure Tunnel (Project 258). NAA S&ID SID 63-163 (April 1963).
6. Dynamic-Longitudinal and Directional Stability Derivatives for a 45-Degree Sweptback-Wing Airplane Model at Transonic Speeds. NASA TM X-39 (August 1959).
7. Structural Analysis of the 0.055-Scale Apollo Wind Tunnel Models. NAA S&ID SID 62-103 (16 February 1962).

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APPENDIX A

PLOTTED DATA

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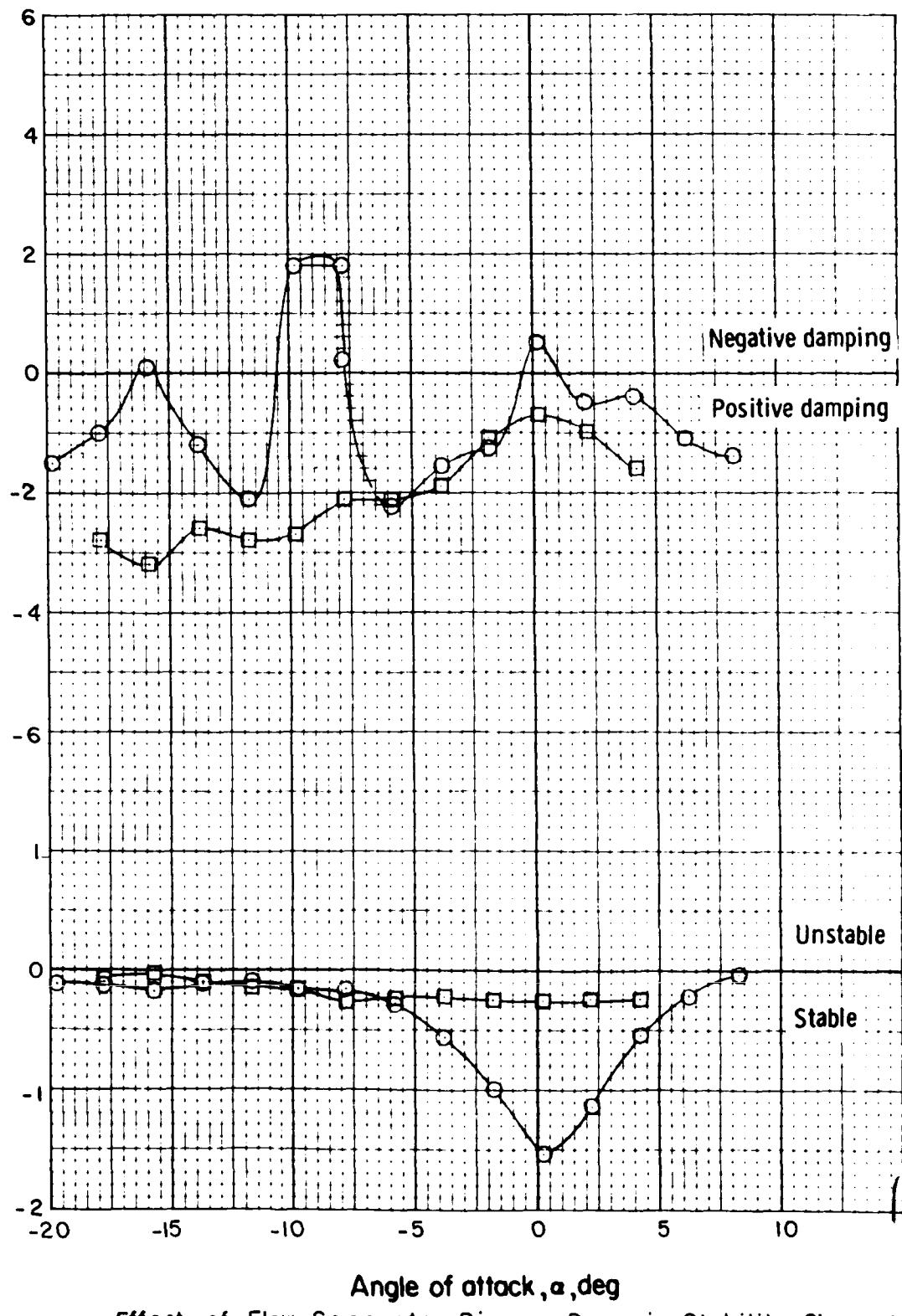
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Hampton, Virginia

- \circ Run 1 - $E_{52} T_{21} C_{19}$ (Disc On)
 \square Run 2 - $E_{51} T_{21} C_{19}$ (Disc Off)

$C_{mq} + C_{m\dot{q}}$
per radian

$C_{m_a} - k^2 C_{m\dot{q}}$
per radian



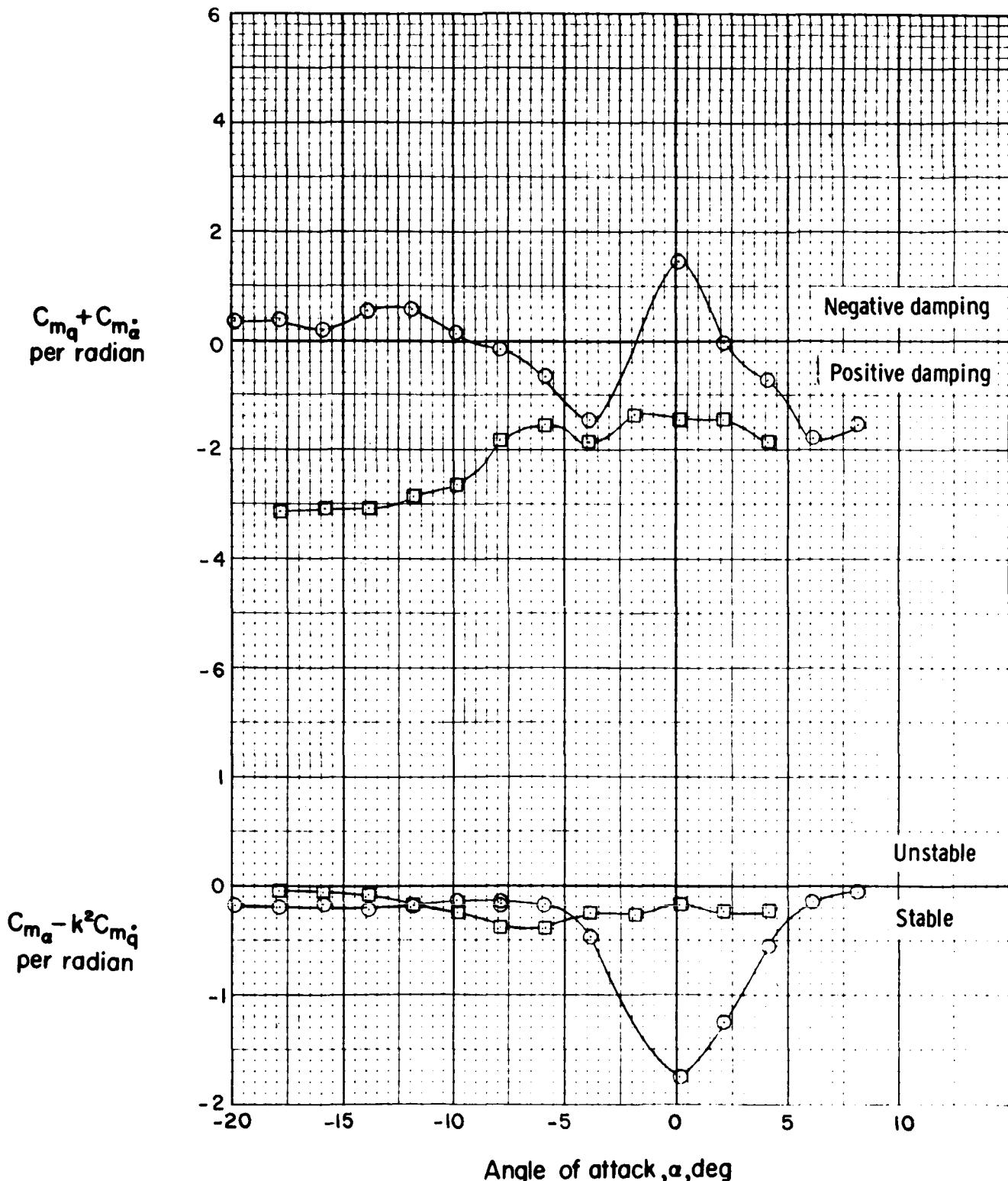
Effect of Flow Separator Disc on Dynamic Stability Characteristics
Launch Escape Configuration, $M = 3.00$ $R = 1.94 \times 10^6$

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 Langley Research Center
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 Hampton, Virginia

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- Run 1 - $E_{52} T_{21} C_{19}$ (Disc On)
- Run 2 - $E_{51} T_{21} C_{19}$ (Disc Off)

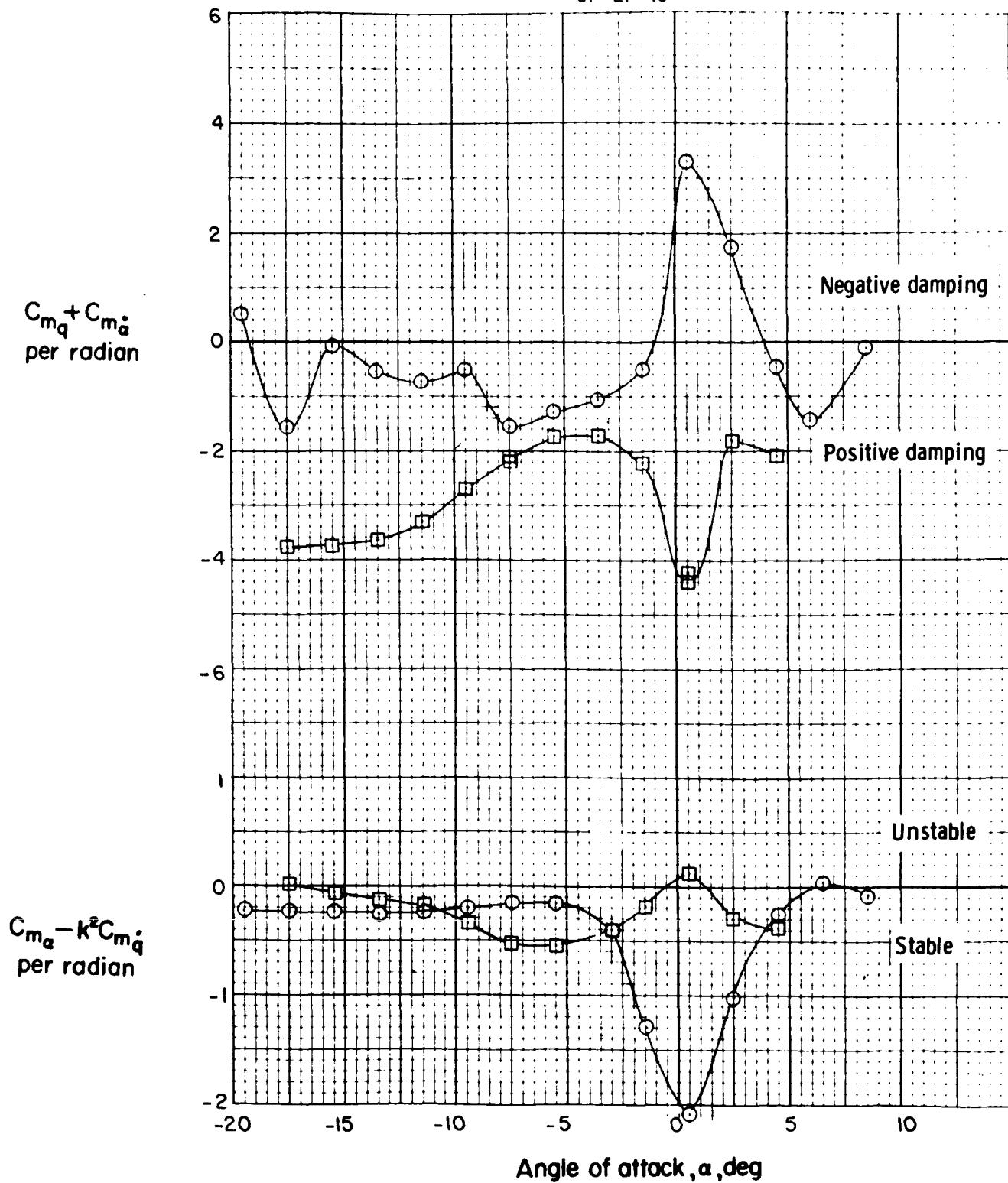


Effect of Flow Separator Disc on Dynamic Stability Characteristics
 Launch Escape Configuration, $M = 3.50$ $R = 2.36 \times 10^6$

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Hampton, Virginia

- Run 1 - $E_{52} T_{21} C_{19}$ (Disc On)
 □ Run 2 - $E_{51} T_{21} C_{19}$ (Disc Off)



Effect of Flow Separator Disc on Dynamic Stability Characteristics
Launch Escape Configuration, $M = 3.96$ $R = 2.05 \times 10^6$

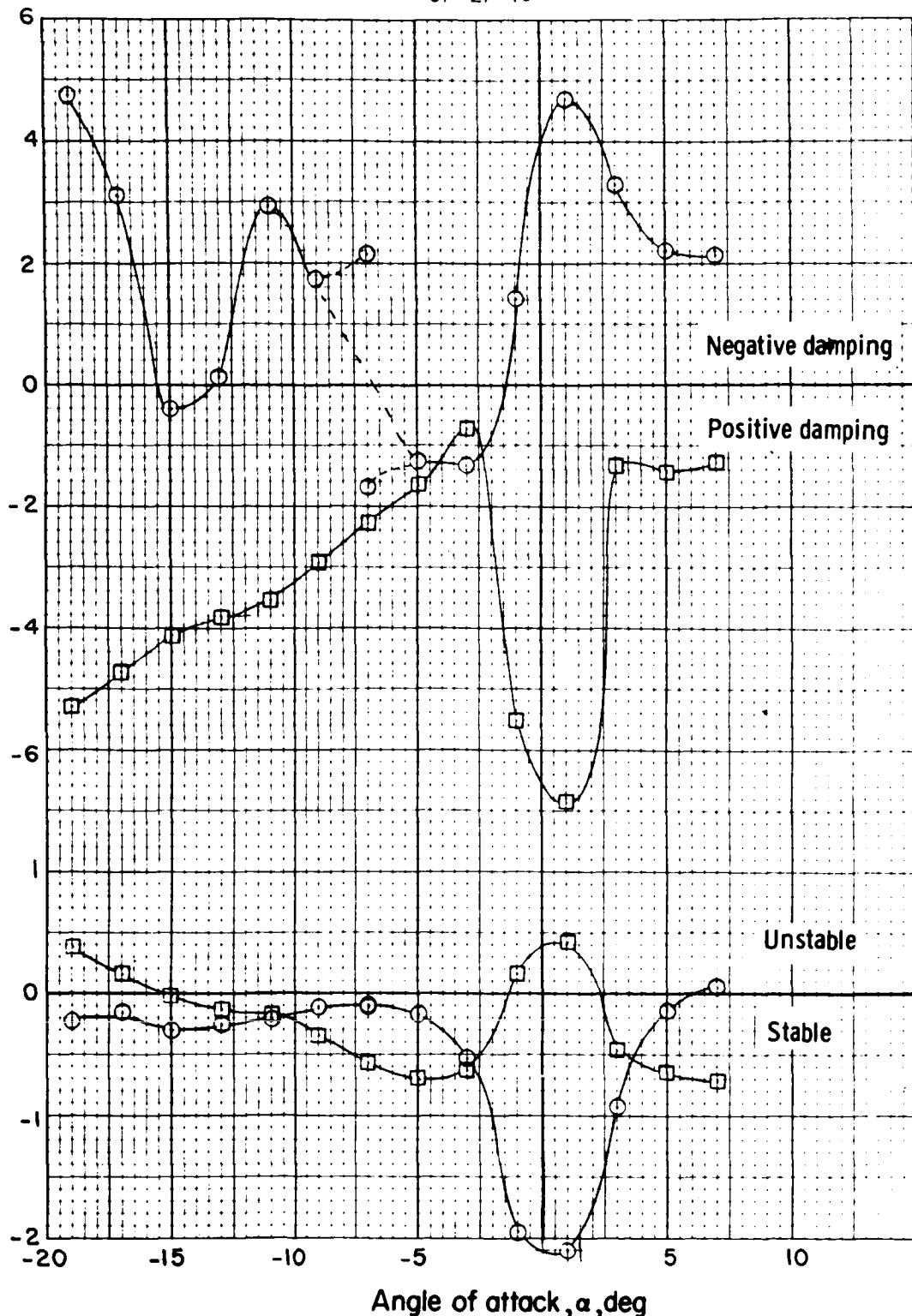
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$C_{m_q} + C_{m\dot{q}}$
per radian

$C_{m\dot{q}} - k^2 C_{m_q}$
per radian

- Run 1 - $E_{52} T_{21} C_{19}$ (Disc On)
- Run 2 - $E_{51} T_{21} C_{19}$ (Disc Off)



Effect of Flow Separator Disc on Dynamic Stability Characteristics
Launch Escape Configuration, $M = 4.65$ $R = 2.63 \times 10^6$

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APPENDIX B

TABULATED DATA

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RUN INDEX

Run	Configuration	Mach No.	Angle Range (deg)	$R \times 10^{-6}$	Page
1	E ₅₂ T ₂₁ C ₁₉ (launch escape vehicle, disc on)	3.00	-20 to +8	1.91	B-4
		3.50	-20 to +8	2.36	B-5
		3.96	-20 to +8	2.05	B-6
		4.65	-19 to +7	2.63	B-7
2	E ₅₁ T ₂₁ C ₁₉ (launch escape vehicle, disc off)	3.00	-18 to +4	1.97	B-8
		3.50	-18 to +4	2.36	B-9
		3.96	-18 to +4	2.05	B-10
		4.65	-19 to +7	2.63	B-11

DATA FORMAT

Item or Column Heading	Definition
Config	Configuration No. 90010 - E ₅₁ T ₂₁ C ₁₉ 90011 - E ₅₂ T ₂₁ C ₁₉
Velocity	Free-stream velocity, ft/sec
Q	Free-stream dynamic pressure, lb/ft ²
R	Reynolds number $\times 10^{-6}$ based on a reference length of 0.706 ft
Theta	Phase angle between driving torque and model displacement, deg
Disp	Amplitude of oscillation, radians
Beta	Angle of sideslip, deg
Alpha	Angle of attack, deg
k	Reduced frequency parameter, $\frac{\omega l}{V}$

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Item or Column Heading	Definition
---------------------------	------------

CMQ	Damping-in-pitch parameter per radian, $C_{m_q} + C_{m\dot{\alpha}}$
-----	---

CMA	Oscillatory longitudinal stability parameter per radian, $C_{m\alpha} - k^2 C_{m_q}$
-----	---

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TEST	411	AT	UPWT	TS2	CONFIG	90011	REFERENCE LENGTH	*706 FT.
RUN	1				MACH NO.	3.000	REFERENCE AREA	.391 SQ.FT.
					VELOCITY	2170.7	TOTAL TEMPERATURE	150 DEG.F.
POINT	Q	R	THETA	DISP.	BETA	ALPHA	K	CMA
19	514.7	1.910	222.73	.0340	.00	7.80-	.0144	.202
20	514.9	1.910	97.34	.0342	.00	5.80-	.0163	2.231-
21	515.2	1.912	95.57	.0343	.00	3.75-	.0197	1.557-
22	515.0	1.911	95.63	.0342	.00	1.80-	.0245	1.291-
23	515.0	1.911	260.62	.0342	.00	.20	.0290	.513
24	515.0	1.911	61.69	.0342	.00	2.20	.0255	.483-
25	515.0	1.911	165.06	.0341	.00	4.25	.0195	.353-
26	515.0	1.911	68.63	.0340	.00	6.25	.0150	1.108-
27	515.0	1.911	112.23	.0340	.00	8.25	.0118	1.355-
28	515.0	1.911	228.40	.0341	.00	7.80-	.0147	1.778
29	515.0	1.911	259.05	.0340	.00-	9.75-	.0143	1.817
30	515.1	1.911	96.73	.0340	.00-	11.75-	.0130	2.133-
31	515.1	1.911	153.99	.0341	.00-	13.80-	.0141	1.239-
32	515.1	1.911	234.08	.0342	.00-	15.80-	.0146	.105
33	515.1	1.911	130.90	.0342	.00-	17.70-	.0138	.988-
34	515.1	1.911	111.87	.0341	.00-	19.75-	.0134	1.495-

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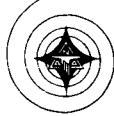
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TEST 411 AT UPWT TS2 RUN 1	CONFIG MACH NO. VELLCITY	90011 3.500 2281.5	REFERENCE LENGTH REFERENCE AREA TOTAL TEMPERATURE	.706 FT. .391 SQ.FT. 150 DEG.F.				
POINT	R	THETA	DISP.	BETA	ALPHA	K	CMA	CMQ
37	542.6	2.362	180.46	.0340	.00	7.85-	.C138	.157-
38	543.3	2.365	151.81	.0341	.00	5.85-	.0142	.665-
39	542.9	2.363	100.24	.0341	.00	3.85-	.0181	.437-
41	543.1	2.364	250.76	.0342	.00	.20	.0301	.458
42	542.9	2.363	209.11	.0342	.00	.20	.0259	.016-
43	542.9	2.363	87.67	.0341	.00	4.20	.0191	.747-
44	543.0	2.364	94.47	.0340	.00	6.15	.0134	.802-
45	542.9	2.363	121.88	.0339	.00	8.20	.0121	.537-
46	542.7	2.362	180.34	.0340	.00	7.85-	.0138	.153-
47	542.8	2.363	190.78	.0340	.00-	9.85-	.0137	.120
48	542.7	2.362	235.94	.0340	.00-	11.80-	.0141	.539
49	543.0	2.364	270.40	.0340	.00-	13.85-	.0144	.521
50	542.5	2.361	285.75	.0340	.00-	15.85-	.0139	.192
51	542.9	2.363	241.63	.0340	.00-	17.85-	.0143	.353
52	543.0	2.364	207.33	.0341	.00-	19.80-	.0143	.323

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TEST	411	AT	UPWT	TS2	CONFIG	90011	REFERENCE LENGTH	•706 FT.	
RUN	11-16-62	MACH NO.	3.960	VELOCITY	2405.3	REFERENCE AREA	•391 SQ.FT.	TOTAL TEMPERATURE	175 DEG.F.
POINT	Q	R	THETA	DISP.	BETA	ALPHA	K	CMA	CMQ
55	429.9	2.058	103.59	.0337	.00	7.45-	.0126	.590-	.170-
56	427.9	2.048	98.93	.0335	.00	5.50-	.0126	.307-	.175-
57	428.3	2.050	97.31	.0336	.00	3.50-	.0152	.049-	.400-
58	428.9	2.053	144.88	.0336	.00	1.50-	.0228	.512-	.301-
59	428.9	2.053	352.28	.0335	.00	.50	.0242	.282	.157-
60	428.5	2.051	253.43	.0337	.00	2.50	.0208	.738	.023-
61	428.4	2.051	165.77	.0334	.00	4.55	.0138	.480-	.259-
62	428.5	2.051	90.47	.0332	.00	6.50	.0098	.442-	.026-
63	428.4	2.051	190.91	.0332	.00	8.50	.0116	.097-	.090-
65	428.2	2.050	126.74	.0335	.00-	9.50-	.0131	.500-	.208-
66	428.4	2.051	147.73	.0335	.00-	11.50-	.0138	.753-	.261-
67	428.3	2.050	119.24	.0335	.00-	13.45-	.0137	.577-	.265-
68	428.6	2.051	199.20	.0335	.00-	15.50-	.0134	.070-	.237-
69	428.3	2.050	140.36	.0337	.00-	17.50-	.0136	.578-	.237-
70	428.6	2.051	290.45	.0336	.00-	19.50-	.0131	.503	.218-

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TEST 411 AT UPWT TS2
RUN 1 11-16-62

CONFIG 90011
MACH NO. 4.650
VELOCITY 2489.4

REFERENCE LENGTH .706 FT.
REFERENCE AREA .391 SQ.FT.
TOTAL TEMPERATURE 175 DEG.F.

POINT	Q	R	THETA	DISP.	BETA	ALPHA	K	CMA
77	431.1	2.629	93.78	.0335	.00	7.05-	.0114	1.696-
78	430.8	2.627	81.08	.0336	.00	5.05-	.0122	1.289-
79	430.8	2.627	106.29	.0337	.00	3.05-	.0160	1.325-
80	430.9	2.628	264.87	.0338	.00	1.00-	.0261	1.965-
82	431.1	2.628	263.34	.0333	.00	.95	.0274	2.193-
83	431.0	2.628	292.23	.0331	.00	2.95	.0191	3.259
84	431.1	2.628	251.93	.0329	.00	4.95	.0120	2.199
85	431.1	2.628	217.85	.0329	.00	6.95	.0096	2.132
86	431.2	2.629	259.74	.0329	.00	7.05-	.0113	2.154
88	430.7	2.626	246.70	.0328	.00-	9.00-	.0116	1.716
89	430.7	2.626	273.85	.0329	.00-	11.05-	.0126	2.951
90	431.0	2.628	193.36	.0330	.00-	13.05-	.0135	.123
91	431.0	2.628	6.25	.0331	.00-	15.00-	.0135	.397-
92	430.9	2.627	263.22	.0330	.00-	17.05-	.0121	.089
93	431.0	2.628	253.38	.0332	.00-	19.00-	.0130	4.725

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TEST 411 AT UPWT TS2
RUN 2 11-16-62

CONFIG 90010
MACH NO. 3.000
VELOCITY 2170.7

REFERENCE LENGTH • 706 FT.
REFERENCE AREA • 391 SQ.FT.
TOTAL TEMPERATURE 150 DEG.F.

POINT	Q	R	THETA	DISP.	BETA	ALPHA	K	CMA	CMQ
12	531.2	1.971	100.27	.0338	.00	7.80-	.0171	.272-	.136-
13	530.8	1.969	103.23	.0337	.00-	9.75-	.0155	.670-	.173-
14	531.9	1.974	102.82	.0338	.00-	11.75-	.0151	.815-	.150-
15	532.6	1.976	97.64	.0338	.00-	13.75-	.0141	.627-	.098-
16	533.1	1.978	101.21	.0337	.00-	15.75-	.0127	.187-	.029-
17	532.5	1.976	106.45	.0338	.00-	17.80-	.0138	.759-	.081-
18	532.1	1.974	97.81	.0339	.00	7.80-	.0171	.126-	.272-
19	532.0	1.974	95.59	.0339	.00	5.75-	.0166	.108-	.242-
20	531.8	1.973	107.80	.0338	.00	3.80-	.0163	.896-	.222-
21	532.1	1.974	128.96	.0339	.00	1.80-	.0168	.067-	.248-
22	532.2	1.975	138.08	.0339	.00	*.20	.0171	.670-	.273-
23	532.2	1.975	119.22	.0340	.00	2.20	.0166	.995-	.243-
24	531.6	1.973	111.75	.0339	.00	4.25	.0165	.557-	.232-

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TEST 411 AT UPWT TS2 RUN 2	UPWT TS2 11-16-62	CONFIG 90010	MACH NO. 3.500	REFERENCE AREA .391 SQ.FT.	LENGTH .706 FT.	TOTAL TEMPERATURE 150 DEG.F.	CMA .385-
POINT	Q	R	THETA	DISP.	BETA	ALPHA	CMQ .822-
27	541.8	2.358	109.33	.0337	.00	7.85-	.0180
28	543.0	2.364	112.39	.0337	.00-	9.85-	.0161
29	543.0	2.364	114.88	.0336	.00-	11.85-	.0149
30	542.6	2.362	102.42	.0336	.00-	13.85-	.0132
31	542.5	2.361	107.92	.0337	.00-	15.80-	.0131
32	543.1	2.364	108.04	.0336	.00-	17.85-	.0129
33	543.0	2.363	95.86	.0342	.00	7.85-	.0179
34	543.0	2.364	100.74	.0342	.00	5.85-	.0181
35	543.1	2.364	98.85	.0341	.00	3.85-	.0161
36	542.8	2.363	103.96	.0342	.00	1.80-	.0163
37	542.9	2.363	107.69	.0342	.00	.15	.0149
38	542.7	2.362	100.32	.0341	.00	2.15	.0156
39	542.4	2.361	101.45	.0341	.00	4.15	.0159

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TEST 411 RUN 2	AT UPWT TS2 11-16-62	CONFIG	90010	REFERENCE LENGTH	• 706 FT.
		MACH NO.	3.960	REFERENCE AREA	.391 SQ.FT.
		VELOCITY	2405.3	TOTAL TEMPERATURE	• 175 DEG.F.
		R	THETA	DISP.	K
42	428.1	2.049	92.80	.0339	.0174
43	427.7	2.047	93.49	.0339	.0155
44	429.3	2.055	103.02	.0339	.0135
45	427.4	2.046	94.28	.0338	.0126
46	428.5	2.051	90.46	.0338	.0118
47	428.4	2.051	97.01	.0339	.0107
48	427.9	2.048	93.76	.0339	.0174
49	427.7	2.047	102.52	.0339	.0175
50	428.3	2.050	100.74	.0338	.0161
51	427.7	2.047	96.74	.0339	.0136
52	428.4	2.051	101.03	.0337	.0087
53	427.7	2.047	101.21	.0339	.0150
54	427.7	2.047	96.24	.0339	.0158
55	428.1	2.049	99.30	.0338	.0085

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TEST 411 AT UPWT TS2
RUN 2 11-16-62

CONFIG 90010
MACH NO. 4.650
VELOCITY 2489.4

POINT	Q	R	REFERENCE LENGTH	•706 FT.
			REFERENCE AREA	•391 SQ.FT.
			TOTAL TEMPERATURE	175 DEG.F.
58	431.2	2.629	92.77	•0336
59	431.2	2.629	93.64	•0336
60	431.3	2.630	96.31	•0336
61	431.3	2.630	96.77	•0336
62	431.2	2.629	97.31	•0336
63	431.2	2.629	93.68	•0336
64	431.3	2.630	172.79	•0339
65	431.4	2.630	93.98	•0340
66	431.0	2.628	98.64	•0341
67	431.0	2.628	115.15	•0341
68	431.1	2.629	95.25	•0340
69	431.3	2.630	173.01	•0346
70	431.0	2.628	100.73	•0345
71	431.1	2.629	118.05	•0346
72	431.0	2.628	109.39	•0347

POINT	Q	R	DISP.	ALPHA	CMA
			THETA	BETA	K
			DISP.	BETA	CMQ
58	431.2	2.629	92.77	•00	•0173
59	431.2	2.629	93.64	•00	•0150
60	431.3	2.630	96.31	•00	•0131
61	431.3	2.630	96.77	•00	•0122
62	431.2	2.629	97.31	•00	•0107
63	431.2	2.629	93.68	•00	•0078
64	431.3	2.630	172.79	•00	•0115
65	431.4	2.630	93.98	•00	•0173
66	431.0	2.628	98.64	•00	•0184
67	431.0	2.628	115.15	•00	•0178
68	431.1	2.629	95.25	•00	•0077
69	431.3	2.630	173.01	•00	•0159
70	431.0	2.628	100.73	•00	•0164
71	431.1	2.629	118.05	•00	•0180
72	431.0	2.628	109.39	•00	•0186

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